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BOOK REVIEWS

Chandra : A Biography of S Chandrasekhar
by Kameshwar C Wali
(A Centennial Publication of the University of Chicago Press : Chicago-London 1991)
x+341 pages, illustrated; price ; US $ 34.50 (Hard Cover); ISBN 0-226-87054-5

This is a biography written by an Indian born particle physicist settled in the United States, who first met Prof Chandrasekhar in 1960. This is not a biography giving the scientific contributions of Chandrasekhar, who has become a legend in his lifetime. It deals with Chandrasekhar as a man, his aspirations, successes and frustrations. The style of writing is so good that it reads like a novel. In writing this book Wali has gone through the Chandresekhar papers in the University of Chicago Archives and has interviewed some fifty colleagues and former students of Chandrasekhar including Dirac, Sagan, Spitzer, Thorne and Weisskopf. This book satisfies a need long felt by the scientific community of knowing how the legendary scientist reached the peak of his fame through numerous hurdles. At the end, he gives excerpts from numerous interviews with Chandrasekhar and we know about his views about many contemporary scientists and about scientific, political and other problems.

To begin with, Wali gives an account of the enlightened and cultured family environment in which Chandrasekhar grew up till he was nineteen. Later we get an account of the family environment of his wife, Lalitha which was no less cultured and enlightened. Chandrasekhar's outstanding mathematical aptitudes were recognised by his teachers very early in life. The Nobel Laureate C V Raman was his uncle. Raman and Ramanujan's success inspired Chandrasekhar in his young age. His mother gave him strong support and encouraged him to become a scientist, unlike his father who wanted him to become an ICS. Already at the age of 17 he read Sommerfeld's "Atomic Structure and Spectral Lines". Next year he had the opportunity of listening to Sommerfeld's lecture and talking to him when he came to India. On Sommerfeld's advice he studied Fermi-Dirac statistics and sent a paper to Fowler for communication to proceedings of the Royal Society at the age of eighteen. Thus began a flurry of activity and he published four papers before going abroad. A scholarship was specially created for him to enable him to pursue his research at Cambridge. He proceeded to Cambridge at the age of 19. His mother encouraged him to go abroad although she knew that she might not recover from her illness.

Chandrasekhar discovered the limiting mass of a white dwarf (now called "Chandrasekhar limit") while sailing to England. Later he met with Eddington, "the most distinguished astrophysicist of his time", who did not believe Chandrasekhar's result.

Chandrasekhar was very much depressed and in 1939 decided to change his line of research after writing a book " An Introduction to the Study of Stellar Structure" where he gave his detailed calculations in proof of the limiting mass.

This was the beginning of his unique style of research. In his own words : "After the early preparatory years my work has followed a certain pattern motivated, principally by quest after perspectives. In practice, this quest has consisted of my choosing (after trials and tribulations) a certain area which appears amenable to cultivation and compatible with my taste, abilities and temperament. And when after some years' study I feel that I have accumulated sufficient body of knowledge and achieved a view of my own, I have the urge to present my point of view *ab initio* in a coherent account with order, form and structure". He has written seven such books on diverse topics.

When quasars were discovered in the early sixties, Chandrasekhar suspected that general relativity might be important for compact objects and began to learn it at the age of fifty. He went on to take account the general relativistic corrections which are important for considering the structure and stability of compact astrophysical objects. He contributed towards the development of Relativistic Astrophysics more than anybody else. He then switched his attention to black holes, the ultimate fate of massive stars. I heard him tell Prof Synge in 1972 that he was astrophysicist and as such was interested in the applications of general relativity to astrophysics. But at that time he had forgotten that he was a mathematician as well. So in 1978, we find him investigating the perturbations of charged black holes which are not likely to exist in nature. This represented slide (in his own words) "downhill, all the way down" for an astrophysicist of real stars. Later, he realised that the same equation involving a complex function described both the black holes and colliding gravitational and electromagnetic waves. So his "slide downhill" continued and the mathematician him dominated over the astrophysicist. The mathematician Chandrasekhar was so enchanted by the beauty of general relativity that he broke loose from the domain of the astrophysicist. He said in his lecture on the occasion of the 150th anniversary of the birth of J W Gibbs "One realizes when wandering through the great hall of general relativity, that what one believed to be Einstein's hall is in fact a corridor leading to Maxwell's hall; and when one is certain that one is examining the gems in Maxwell's hall one has inadvertently slipped into Einstein's hall. So matchless is the beauty that Einstein has imparted to it".

Few of us know that Chandrasekhar is an avid reader of English literature and a lover of classical Western music. In his old age, he tries to find a parallel between the beauty of art and music and the mathematical beauty of general relativity. Weisskopf said, "He has an incomparable style. Good English style is a lost art in physics but he has it and this wonderful feeling for the essential and a feeling for beauty". Spitzer said, " It is a rewarding aesthetic experience to listen to Chandra's lectures and study the development of theoretical structures at his hands. The pleasure I get is the same as I get when I go to an art gallery and admire painters". Chandrasekhar writes about his style of writing "I acquired my style from not only just reading, for instance the essays of T S Eliot, Virginia Woolf and Henry James but also paying attention to how they write—how they construct sentences and divide them into paragraphs, do they make them short or long? For example the idea of just using one sentence for a paragraph or a concluding sentence without subject or object "just a few words......so it is......".

Another contribution of Chandrasekhar to science was his decisive role in transforming Astrophysical Journal from a private journal of the university of Chicago into the national journal of America. For nineteen years from 1952 to 1971 he was an autocratic editor but he did not allow his extra responsibilities to interfere with his research work. He was impervious to criticism. He avoided social contacts in order to remain impartial in his decisions as editor.

Chandrasekhar could handle horrendously complicated calculations even at the ripe old age of seventy five, sometimes single handed and sometimes with the help of one of his students. He could get solutions to such problems which distinguished workers like Hartle, Chitre and Thorne could not believe as being solvable without the use of computers. Chandrasekhar was really a physicist, mathematician and a human computer all in one.

Chandrasekhar seldom chose the conventional path. He was always guided by an inner urge in his research and most of his work was away from the mainstream of research. Sometimes he showed a new direction and attracted others to a field which had been considered uninteresting previously. Even at the ripe old age of 82, his enthusiasm has not declined and he does not hesitate to explore new areas of research. He has aptly been called "a lonely wanderer in the byways of Science".

This volume will definitely inspire young workers in astrophysics to continue the quest for knowledge in the way Chandrasekhar did for more than six decades.

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Selected Papers; Vol 3 : Stochastic, Statistical and Hydromagnetic Problems in Physics and Astronomy

by S Chandrasekhar

The University of Chicago Press : Chicoga-London, 1989
xii + 642 pages, illustrated; price $ 34.50 (Paper back); ISBN 0-226-10095-2

The contents of the Volume III of Prof S Chandrasekhar's 'Selected papers', can be broadly classified under four separate headings :

Part I Dynamical Friction and Brownian Motion,
Part II Statistical Problems in Astronomy,
Part III Statistical Theory of Hydrodynamics and Hydromagnetic turbulence,
Part IV Hydromagnetic Problems in Astrophysics.

Though the sections deal with different aspects of physical processes, there is one common link between them all. Statistical analysis, as applied to day to day physical phenomena, has been extended to the field of stellar dynamics and astrophysics.

To begin with, Prof Chandrasekhar considers certain fundamental probability methods, which are finding applications in a wide variety of problems and fields such as stellar dynamics. A common characteristic of all these problems, is that here one aims to study a property which is the result of superposition of a large number of random variables.

One of the principal problems in stellar dynamics is concerned with the analysis of the nature of the force acting on a star which is a member of a stellar system. We may broadly distinguish the forces as (i) the influence of the system as a whole and (ii) the influence of the immediate local neighbourhood. The former will be a smoothly varying function of position and time. The latter will be subject to relatively rapid fluctuations.

The idea of dynamical friction experienced by a star is also very interesting. The author has demonstrated that a star must suffer cumulatively a larger absolute amount of acceleration in the direction opposite to its direction of motion, than in the direction of motion. These are exactly what are implied by the existence of dynamical friction.

Spatial correlations developed by him is extended to the discussion of stability of binary stars. Jeans has emphasized that the statistics of binary stars provide an important basis for drawing conclusions regarding the time–scale appropriate for the galaxy.

One of the triumphs of classical physics was the unraveling of the phenomenon of Brownian motion by Einstein and Smoluchowski. Centred around these early investigations, there has been rapid strides in the theory of probability and random variables. Starting from stellar dynamics, Prof S Chandrasekhar has illustrated how Einstein's idea can have a fruitful application in a different field altogether.

In a series of papers, which constitutes the the second part of his work Prof Chandrasekhar has developed the integral equations governing the fluctuations in the brightness of the Milky Way, and solved them under some special circumstances. His papers on stellar scintillation and astronomical seeing provide a basis for discussing certain aspects of the phenomena that were previously lacking.

In part III, Prof Chandrasekhar has found explicit solutions for the spectrum of turbulence when the conditions are stationary, when the conditions are non-stationary and the turbulence is decaying. Later, he develops the invariant theory of isotropic turbulence in magneto-hydrodynamics.

The work on density fluctuation leads to a very interesting conclusion that we might trace to gravitational instability as the original cause for the present highly irregular distribution of the interstellar matter. The condition for the occurrence of turbulence when an incompressible fluid is heated from below requires careful examination. Prof Chandresekhar studies this field in a number of papers and draws some interesting conclusions. Finally, he has drawn the attention of the readers to the fruitful applications of the theory of turbulence to astrophysical problems. Prof Rosseland first pointed out the importance of astrophysics of turbulence with correct hydrodynamical meaning. Stuve and Ehey established the occurrence of large scale motions in the atmospheres of stars like 17 Leporis, ε Aurigae and α-Perses. Prof Chandrasekhar's article 'Turbulence—A Physical Theory of Astrophysical Interest', is instructive, informative and perhaps of great use to workers in Astrophysics.

The hypothesis of the existence of a magnetic field in galactic space has received some confirmation by polarization of the light of the stars. Prof Chandrasekhar describes methods to estimate the magnetic field. His paper in association with E. Fermi, deals with the problem of gravitation of cosmical masses of infinite electrical conductivity in which there is a prevalent magnetic field. These papers along with other articles on different aspect of intergalactic magnetic field is of high intellectual value.

Present 'Selected Works' of Prof Chandrasekhar will be of great use to the workers in Astrophysics. His works speak of great foresight especially when observational information were not much. But the recent advances in experiments will encourage the astrophysicists to revisit Prof Chandrasekhar's works. Mathematics used in his works is not beyond comprehension though sometimes the approximations may appear intricate.

A previous knowledge of 'Statistical Distribution Theory' will however go a long way in supplementing the readers, to obtain a wider perspective of Prof Chandrasekhar's seemingly complicated findings.

To conclude, we may say, that any observable scientific phenomena is governed by a system of variations. But in order to be able to pursue advanced studies in such spheres, one must arrive at means of representing these variations as much as possible, by some suitable forms. It is at this critical juncture that 'Stochastic Distribution Theory' emerges in an alluring role, and the author has, in fact, made an extensive use of these theories in his bid, to trap the seemingly elusive-be it the fluctuations in brightness of galaxies, or intensity of fields, chaotic motion of stellar particles or the spectrum of hydromagnetic turbulence.

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High Energy Radiation from Magnetized Neutron Stars

by Peter Mészáros

The University of Chicago Press : Chicago-London, 1992

546 pages, 177 figures; price $ 45.95 (Paper back); ISBN 0-226-52094-3

This is a comprehensive and up-to-date treatment of one the most interesting problems in astrophysics. This problem is to achieve an understanding of the physical mechanisms leading to the generation of high energy radiation in neutron stars. This means interpretation of the observational data on the spatial distribution, luminosities, spectra, polarization, and temporal structure of pulses of such radiation in terms of physically consistent models. Such models cannot be constructed without detailed considerations of some exotic radiative and transport processes in the outer plasma envelope dominated by strong magnetic fields. The construction of neutron star models involves a lot of challenging theory which is almost untested experimentally and which continues to fascinate theoreticians since the prediction and even more since the subsequent discovery of neutron stars.

In this book, the author has adopted a theoretical approach. The first half of the book deals with the theory of radiative and transport processes likely to occur in neutron star environments in unusual depth, detail and clarity. In the second half the author proceeds to review the latest observations on different types of neutron star sources and the various models proposed to explain those observations.

Thus the first half of the book, comprising of seven chapters, dealing with atomic physics in ultrahigh magnetic fields and transfer of high energy radiation through a magnetized plasma, gives a thorough introduction to many theoretical tools and concepts of central importance. Many of the topics discussed have not been treated in any monograph so far, and though original research papers have been referred, the treatment is reasonably complete. The processes discussed collectively determine the characteristics of the observed radiation and discussions of the theory of such processes are generally followed by indication of physical situations in which those processes may be of importance in a neutron star.

In the first chapter providing an overview of the subject, the author straightway goes to a brief description of the formation process of neutron stars. The existence of a maximum stable mass for degenerate stellar configurations is inferred from a rough estimate of non-relativistic and relativistic degeneracy pressure. This phenomenon leads to qualitatively different states of matter in the outer crust, inner crust and core. Knowledge of the energy sources which a neutron star can convert to radiation leads to an estimate of the luminosity of such a star.

From the second to the fourth chapter, nonrelativistic theory has been used. Quantum mechanical treatment of particle motions leading to radiation is essential at high fields, and the second chapter is concerned with the eigenvalues and eigenfunctions of a free electron and a hydrogen atom in a magnetic field as derived from the nonrelativistic hamiltonian operator. Condensed matter effects are mentioned, and finally, a brief sketch of classical and quantum electrodynamics in strong fields is presented.

The third chapter deals with nonrelativistic wave propagation in a magnetized plasma. Starting with Maxwell's equations, the author derives the dielectric tensor in the presence of an external magnetic field and the dispersion relations and polarization properties of a wave propagating in an arbitrary direction with respect to the field. A quantum description of the dielectric tensor is then given using first-order perturbation corrections to time-dependent wavefunctions of electrons due to the presence of the propagating wave. For very strong fields, the contribution of virtual electron-positron pairs to the complex refractive index and normal mode polarization vectors cause several critical points to appear where normal propagation modes may not exist. A cold plasma description is not realistic for a discussion of mode structure of the propagating field in the neighbourhood of these critical points. Thermal effects are included by expressing the susceptibility tensor containing Doppler and recoil effects as the superposition of susceptibilities due to electrons in different Landau levels. Consideration of wave propagation then gives damping in the hot plasma wave due to purely thermal effects. Finally, the ambiguities in the normal mode picture of wave propagation in terms of a set of polarization vectors are pointed out and what exactly happens to the propagating wave near a critical point is indicated.

The fourth chapter deals with nonrelativistic magnetized radiative processes. It starts with an account of classical and quantal cyclotron radiation since the case of classical emission at the lowest harmonic is close to the situation encountered in strong magnetic field accreting neutron stars for particle energies in the X-ray range or below. Next, classical and quantum treatments of scattering cross section of a transverse plane polarized monochromatic wave by an electron gyrating around a magnetic field is given and the vacuum polarization effects on such processes is discussed. Using a nonrelativistic quantum approach, the differential scattering cross section in a hot plasma is obtained by averaging the scattering rate for a moving electron over an electron longitudinal momentum distribution along the magnetic field. The motion causes a difference between the photon frequencies in the laboratory and electron rest frames. A modification of the normal mode structure occurs. This has been discussed in the framework of the scattering amplitudes given. A simple quantum treatment of bremsstrahlung follows a brief qualitative discussion of radiationless Coulomb collisions of electrons in the presence of a strong magnetic field. Finally, a simplified kinetic equation for electron population in Landau levels in presence of these processes, is given and the thermal broadening of resonant absorption in a hot nonrelativistic plasma due to the contribution of the photon momentum term is discussed.

However, a complete description of many high-energy radiative processes is obtained only within the framework of relativistic QED. Such relativistic radiation processes are dealt with in Chapter 5. Using the relativistic expression for the S-matrix, the rates of Compton scattering and two-photon decay in a magnetic field as well as that of the simpler one photon process of cyclotron emission and absorption are derived. Manifestations of these specific microprocess in the radiative transport problem, however, takes place through their effect on the statistical behaviour of the plasma which involves averages over the electron momentum distribution for each set of photon parameters. Performing these averages after taking into account the conservation of energy and momentum, we get redistribution functions between well-defined initial and final photon states for all processes involving single and multiple photons. Then the relativistic polarization tensor is calculated.

In Chapter 6, the equations of radiation transport in strongly magnetized plasmas are presented. Numerical solutions of transfer equations are given, taking into account all nonlinear scattering and emission processes using relativistic cross sections.

The first two chapters (Chapters 7 and 8) of the second half of the book give beautiful reviews of observations of the accreting X-ray pulsars and rotation powered pulsars respectively, together with a variety of models of the dynamics of the accretion and the rotation process proposed to account for the observations. The discussion of the accretion process in particular, provides a framework for a thorough understanding of the phenomenology of these comparatively well understood types of neutron stars on the basis of very recent theoretical and observational works. Descriptions of structure and energetics of the rotating pulsar magnetosphere in the framework of a magnetic dipole model including relativistic particle outflow have been presented as successful accounts of the observed features of rotation powered pulsars.

The ninth chapter is concerned with the controversial gamma-raybursters, discovered accidentally by surveillance satellites. Here again, an overview of the observations is first presented, followed by some tentative models in which the source is taken to be a magnetized neutron star. Some of the proposals to account for the γ-ray burst energy, the time-scale of the bursts and the lack of strong X-ray emissions include thermonuclear explosions, sudden accretion, neutron starquakes and major angular momentum change due to a sudden perturbation.

Next the super high-energy gamma ray production from well known neutron star sources has been discussed in a similar manner. The last chapter is on evolution of neutron stars. Starting from the formation of a neutron star with a supernova explosion or with an accretion induced collapse of a white dwarf, the author gives a review of the evolution of low mass and high mass neutron stars in X-ray binaries through mass-exchange within the binary system and mass loss outside. The processes accounting for the change of mass, effective surface temperature, orbit, angular momentum, and magnetic fields of isolated neutron stars are also discussed.

This book will serve as a nice reference of both the underlying theories and observational results for research workers interested in the physics of neutron stars.

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Useful Optics (Chicago Lectures in Physics)
by Walter T Welford

The Chicago University Press : Chicago-London, 1991
140 Pages, illustrated; price : $ 14.95 (paper back); ISBN 0-226-89306-5

In publishing an excellent modern book dealing with the practical aspects of optical components used in a laboratory, Chicago University Press has done a commendable job. Because the need for the presence of this type of book was long felt by the professionals and students alike. In most of the text books on optics, the practical aspects which is the crucial part of designing of optical experiment, often seemed to be burried under the volume of other material. So the advent of Useful Optics is a pleasant surprise to the research community.

As this book is an outgrowth of lectures given by Walter T Welford to the graduate students of Chicago University, the vigorous proof of formulae have been kept out intentionally. The book comprise of sixteen small chapters. In Chapter 1, briefly the four useful models of optics viz. (i) quantum optics, (ii) electromagnetic waves, (iii) scalar waves and iv) geometrical optics, connected with detection and of noise present in detection; reflection and transmission at surfaces and different laser modes; diffraction, interference and scattering problems; light collection and image formation have been discussed. In Chapter 2, three dimensional vectorial form of Snell's Law of refraction—a less familiar thing and the equivalence of this with Fermat's principle have been explained in short. The third chapter delineates the image formation by symmetrical optical systems in the framework of Gaussian Optics.

The reader is introduced to the image formation by a combination of mirrors and different types of prisms in Chapter 4, particularly, about those used frequently in optical experiments. Practical knowledge about the transparent materials used in uv, visible and infrared studies is very important. Chapter 5 helps reader to be able to understand and use the manufacturers' catalogue relating to above materials as per specific requirement.

When a complete optical system is designed, the aberration correction is a most vital thing to remember. Author discusses in Chapter 6 about different kinds of aberrations and their correction in optical design. Using Scalar wave theory in Chapter 7, Welford discusses the limits of image formation and the problems of Coherent illumination and laser speckle in an exquisite way. In Chapter 8, the different types of illumination for image forming systems and their quantification *i.e.* the concept of radiometry, have been discussed with useful hints for practical purpose.

The most important thing in lasers other than its monochromatically and coherence so far as the application is concerned, is beam profile. Actually the knowledge of manipulation of beam profile, which embodies Chapter 9, may be gainfully used in optical experiments. Another useful thing is described in Chapter 10 is about thin film multilayers. In a nutshell, the necessary theoretical background is given here with a view to utilize it in antireflection coating, polarising beam splitters, interference filters etc.

The idea of interferrometry, coherence and the motion of monochromatic light have been given in Chapter 11. A discussion about different types of detectors and radiation sources in Chapter 12 with special emphasis on the ways of noise reduction is worth mentioning. The absence of discussion about ultraviolet sources is very much felt here.

Different types of image scanning devices and beam deflectors have been discussed in Chapter thirteen. As a preview of holography and its applications, which is discussed in

Chapter 15, the diffraction gratings as dispersive device, the author discusses in Chapter 14 in a inimitable way.

Last but not the least, in the final Chapter a discussion about the assembling of experimental optical system on the basis of knowledge gathered in preceding sections has been presented. The bibliography section is quite up-to-date which gives detail and vigorous proof of formulae used in this book.

Considering the crisp information regarding optical components delivered in a lucid way in this book, the reviewer strongly feels that the scientific community whose interest lie in optics and related area will be benefitted enormously by having the book as handy reference by the laboratory bench.

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Vibration and Coupling of Continuous Systems : Asymptotic Methods
by J S Hubert and E S Palencia

Springer-Verlag : Berlin-Heidelberg -New York London-Paris-Tokyo Hong Kong, 1989
xv+ 121 pages, 88 figures, price DM 138.00 (Hard Cover), ISBN 3 540 19384-7

The book consists of nine chapters. Chapters I and II deal with the classical vibration theory of systems with discrete spectra. In Chapter I the abstract classical theory of vibration for systems with many degrees of freedom has been presented, while in Chapter II some examples are given.

In Chapter III, the authors present the principal results of operators and spectral theories which are used throughout the rest of the book. Some examples of nonstandard vibrations and coupling are included in Chapter IV. Viscous and thermal effects as well as systems with a continuous spectrum are also discussed in this chapter.

Of concern in Chapters V and VI, is the theory of spectral perturbation. Proofs of several theorems on implicit eigenvalue problems, which often appear in various applications are also included in this chapter. A brief exposition of formal asymptotic methods, matched asymptotic expansions and the two-scales methods have been employed in the analysis of certain complex physical problem dealt with in the sequel.

Several examples of vibrating systems having a small parameter, studied by perturbation theory are discussed in Chapter VII. These include, in particular, systems formed by stiff and soft parts, a discussion on effects of small viscosity and systems with concentrated masses.

Chapters VIII and IX are devoted to acoustic vibrations in unbounded domain and their coupling with an elastic body. The spectral theory of the Helmholtz equation in an exterior domain, including the asymptotic behaviour of the solutions of the wave equation as $t \to \infty$ with special emphasis on scattering frequencies, occupies its place in Chapter VIII. These results have been applied in Chapter IX to some coupled systems, *viz.* vibration of an elastic body immersed in a fluid (compressible or incompressible), including low- and high frequency phenomena and the Helmholtz resonator.

The approach of the book is quite systematic. It will be of much interest to Applied Mathematicians and to people working in the area of Solid Mechanics.

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